Metamorphic Rocks

Metamorphism ("change form") == solid state change in rock structure and mineralogy caused by heat, pressure, or chemically active fluids.

- Higher T & P than lithification
- **New minerals** form by solid-state recrystallization
- **No change to bulk composition** (same atoms present)
- like cooking – NO MELTING

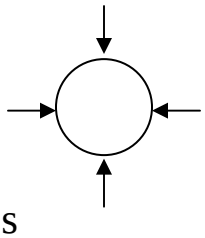
Heat (150°C – 900°C)

- Geothermal Gradient -Temp. change w/ depth = 15° – 30°C / km [30°C / km * 30km = **900°C**]
- Cause chemical reactions – atoms move, recombine, bonds break and reform.
- Weakens xls and allows plastic flow

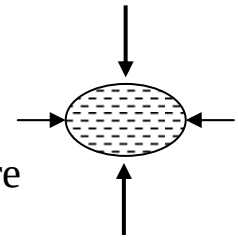
Pressure (up to 10,000 atms. (10 kilobars))

- Pressure Gradient – change w/ depth = ~ 250 bars/km
- 5km – 35km depth [250 bars/km * 35km = 9 kbar)
- caused by burial & tectonic stress
- recrystallization into closer packing order ”high pressure minerals” (polymorphs)

- Lithostatic stress – burial, equal in all directions



- Differential stress – maximum compressive stress
  - ”uneven” stress causes folds and foliation (layers)
  - platy mineral xls grow in direction of lower pressure :. foliation



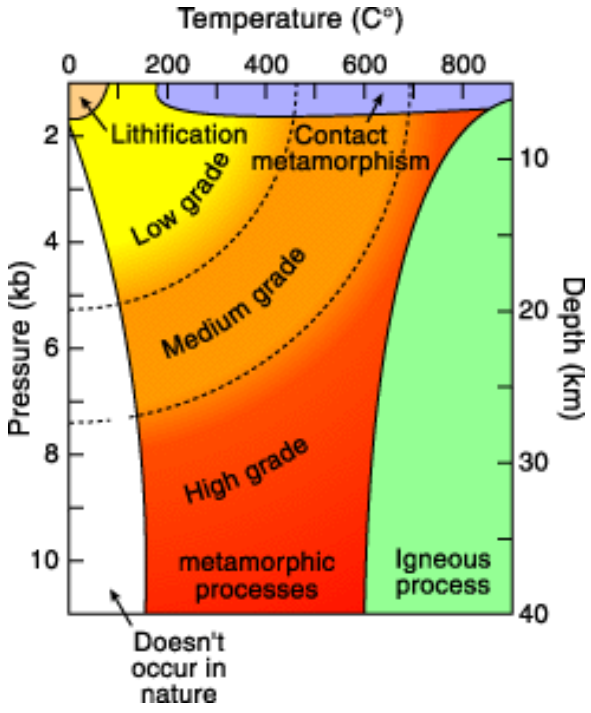
Fluids

- Hot water (also: CO_2, oil & methane)
  - Dissolve ions,
  - Transport ions from high pressure to low pressure (km's)
- Origin: water in buried sed., dehydration of minerals, magmatic intrusion

Metamorphic Grade

== intensity of metamorphism: how high the T & P

- Low grade – lower T & P
- High grade – higher T & P
- higher grade = more changed



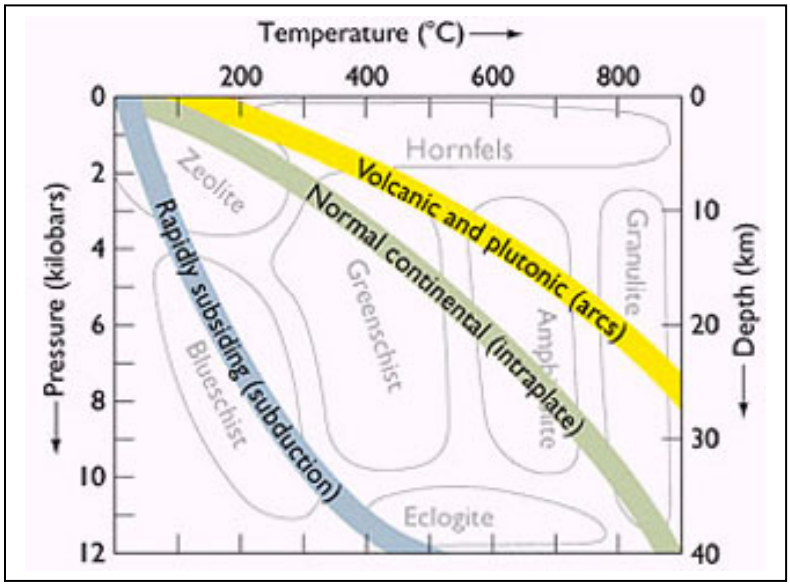
Particular minerals exist under particular T

- High & low pressure or temp. miner
- ∴ some <u>combinations</u> of minerals ar
- minerals present tell of max. T & P conditions
- areas can show bands of meta zones or ***facies*** (fig. 9.21, pg 263)

<-- Increasing Grade --

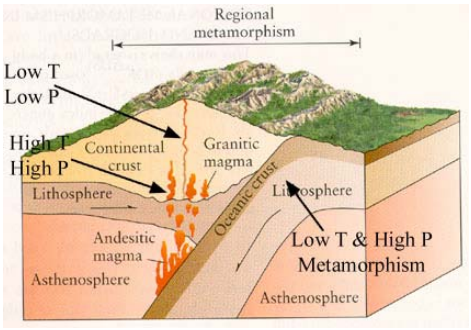
Index Minerals

chlorite
muscovite
biotite
garnet
staurolite
kyanite
sillimanite

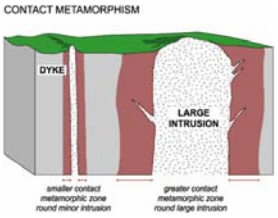


Types of metamorphism (settings)

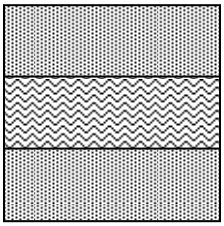
1) regional ("Barrovian") (baking) – most common
    a. compressive stress due to:
        i. burial (lithostatic)
        ii. plate tectonic stress (differential)
            1. behind subduction zones
            2. continental collisions
    b. large scale, over 1,000's of kms
    c. often with belts of differing grades



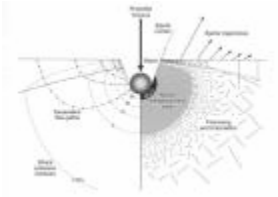
2) contact (frying)
    a. country rock around intrusions



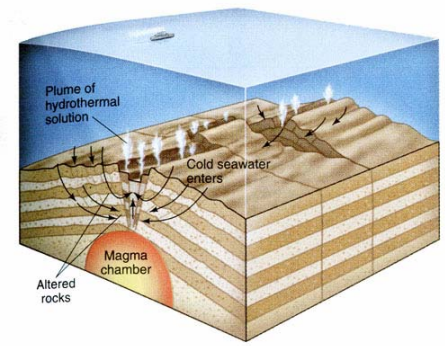
3) shear
    a. ground rock under high pressure in shear zone of fault
    b. slickensides – polished striated surface
    c. cataclastic texture
        i. shallow = fault breccia (*cataclasite*)
        ii. deep = *mylonite*



4) shock
    a. meteor impacts
    b. stishovite (High-P quartz) only here (and deep)
    c. KT boundary enriched with microtektites? (*Chicxulub*)



5) hydrothermal alteration
    a. mid-ocean ridges, hot springs
    b. economic mineral deposits Cu, Au, Pb, Zn



Identification of Metamorphic Rocks (Lab #7)

Based on….

- texture – most important (foliated vs. nonfoliated)
- mineral content (grade of minerals, index minerals)

Foliated rx (L "*leaf*" folio) (**not** the same as bedding)

- Foliation perpendicular to greatest stress direction also perpendicular to fold axies ("schistosity")

Examples:

<-- Increasing Grade --

- **slate** – fine grained, platy minerals (mica) align, form planes of weakness
- **phyllite** – imperfect slatey cleavage w/ shiny mica "sheen"
- **schist** – coarser grained, bigger xl, >50% platy minerals (mica), *shiny*, some mineral segregation (dark/light layers)
- **gneiss** – mineral segregation, banded some times w/ phorphyroblasts "augen" *eyes*, doesn't split
- **migmatite** – ("mixed") partial melting of qz & feldspar, cross between gneiss & granite

Nonfoliated rx (generally equigranular)

<-- Increasing Grade --

- **skarn** – calcite + garnet, pyroxene, etc. Contact meta. (lmstone)
- **quartzite** – massive, fine grained sugary texture, from sandstone
- **marble** – light colored, granular, from limestone (will fizz)
- **hornfels** – v. fine xls, contact meta., like slate without foliation
- **granulite** – pyroxene & garnet
- **amphibolite** – interlocking hornblende (amphibole) xls

Generally higher grade = coarser grained (more xl growth)
Names modified by predominant minerals

1. garnet gneiss
2. muscovite schist